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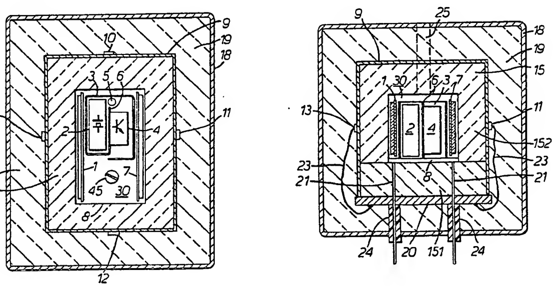
(54) Frequency sources

(57) A frequency source uses a temperature controlled crystal 2 in an oscillator circuit. The crystal is held precisely at a required temperature by surrounding it with a thermal radiator 3, e.g. of copper foil, which is heated by a controllable heat source 4, and a temperature sensor (thermistor) 5 is used to monitor deviations from the required temperature. The oscillator circuit and a temperature control circuit of which the heat source 4 and the thermistor 5 form parts, are all mounted in very close proximity to the crystal so as to minimise temperature differences. These two circuits and the crystal are surrounded by a thermally insulating material 15 and enclosed in a relatively large container 9 having temperature controlled walls e.g. of copper. The wall temperature is held at a value which is less than the temperature of the crystal but significantly above the ambient temperature in which the frequency source is to be operated, by PTC thermistors 10—13 coupled to the walls of the container, which in turn is mounted within a larger enclosure 18 with further thermal insulating material 19 between the container and the enclosure. The oscillator and temperature control circuits are on respective ceramic substrates 1, 7 mounted on a base 8. The heat source 4 is a transistor mounted adjacent a portion 6 of the radiator 3 extending between the heat source 4 and crystal 2.

FIG. 1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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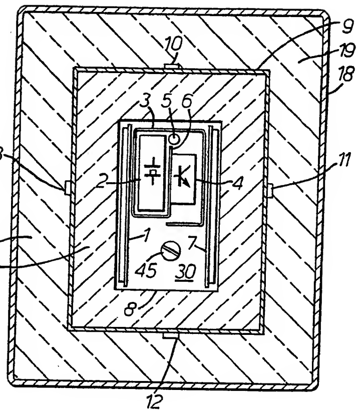
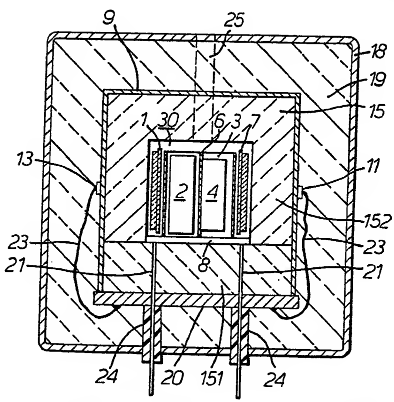


9
10
19
18
3
5
6
13
11
2
4
1
1
7
15
45
30
8
12

FIG. 1.



9
25
18
19
15
1
30
6
3
7
13
11
2
4
152
23
23
21
8
21
24
20
151
24

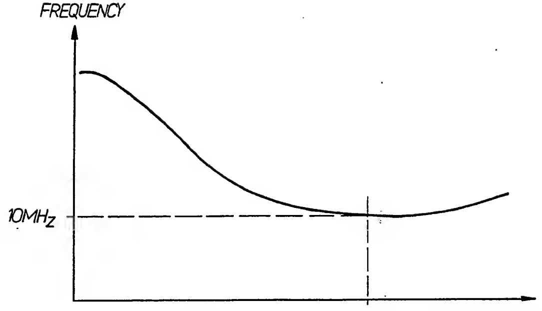

FREQUENCY
10MHz
75°C
TEMPERATURE

FIG. 2.

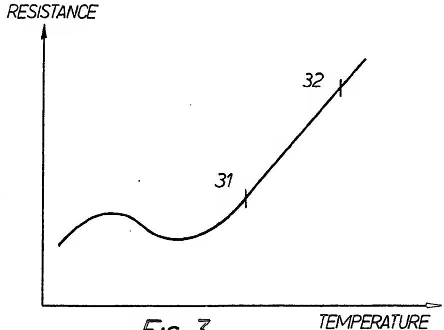

RESISTANCE
32
31
TEMPERATURE

FIG. 3.

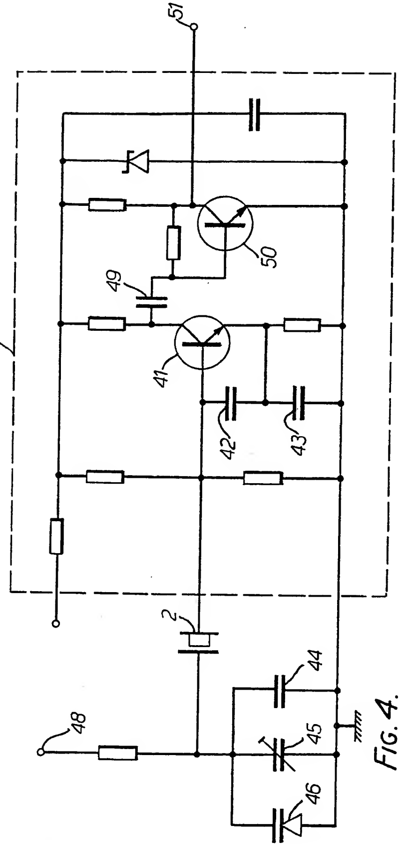


FIG. 4.

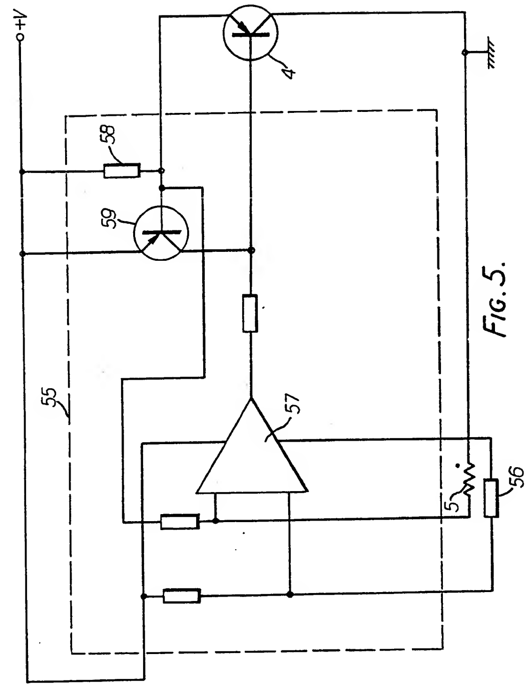


FIG. 5.

SPECIFICATION
Frequency sources

This invention relates to frequency sources of the kind which use a crystal to determine the frequency of an oscillator. The frequency of oscillation of a crystal is temperature dependent and it is usually necessary to carefully control the temperature of the crystal if a stable frequency having a precisely predetermined value is to be obtained. The present invention seeks to provide a frequency source which is capable of providing a particularly stable output frequency which is not significantly affected by changes in temperature of its environment.

According to this invention, a frequency source includes a crystal controlled oscillator circuit; a common heat source operative to heat both the crystal and the oscillator circuit, which determines the frequency of the frequency source, to a required temperature; a temperature sensor operative to detect deviations from the required temperature and to control the heat source to compensate for the deviations; and a radiator of heat arranged to be heated by the heat source and which closely surrounds the crystal and the temperature sensor, and which is in close proximity to said oscillator circuit.

The radiator itself is preferably formed of a thin walled material which is a good conductor of heat, such as a copper foil, and which is arranged to also surround the heat source. In order to minimise undesired temperature gradients the heat source and the crystal are located immediately adjacent to each other with a portion of the radiator being positioned between them. Both the crystal and the heat source may be in contact with the intervening portion of radiator.

The frequency of the oscillator is influenced by the characteristics of the oscillator circuit of which the crystal forms a part.

Preferably, therefore, the oscillator circuit itself is positioned very closely adjacent to said radiator so as to be maintained substantially at the same temperature as the crystal.

The temperature sensor forms part of a temperature control circuit which utilises the output of the temperature sensor to control the heat generated at the heat source, and preferably the temperature control circuit is also mounted very closely adjacent to said radiator so as to be maintained substantially at the temperature of the crystal.

In order to further enhance the stability of the frequency source, the major portion of the oscillator circuit, and the major portion of the temperature control circuit are formed on ceramic substrates. The substrates would typically be alumina, which is a very stable and inert material. Furthermore, it is possible to fabricate circuits on a ceramic substrate using known techniques so that they are extremely small and compact. In this way, the whole of the circuits can be positioned in very close proximity to the radiator which need be little larger than the crystal and heat source which it surrounds.

Thus the two circuits and the previously mentioned parts of the frequency source form an assembly which is capable of having a very small size. Conveniently the assembly is formed on a relatively rigid and robust printed circuit board, which also provides the necessary electrical interconnections. Preferably the assembly is mounted within a closed container with thermal insulating material being present between the assembly and the inner surface of the container; and means are provided for maintaining the surfaces of the container at a predetermined temperature which is less than the temperature of the crystal.

Conveniently, the thermally insulating material is one which has a closed cellular structure, such as an expanded polyurethane.

Preferably a plurality of temperature sensitive devices are mounted at the surface of the container and are operative to minimise the occurrence of temperature gradients in the walls of the container. The container preferably has thin walls which are formed of a material having a very good thermal conductivity, in which case the temperature sensitive devices can be positioned on the inside or the outside of the walls so as to be immediately adjacent thereto.

This container, having a temperature controlled surface, is mounted within a larger container with further insulating material positioned between the two containers.

By providing a significant temperature difference between the assembly which includes the crystal, and the surface of the inner container, a constant and controlled heat loss can be achieved enabling the temperature variations which occur at the crystal to be minimised. In practice, the temperature at which the inner container is stabilised is significantly above the expected ambient temperature of the surroundings in which the frequency source is designed to operate.

The invention is further described by way of example with reference to the accompanying drawings, in which

Figure 1 shows plan and elevation views of a frequency source in accordance with the invention,

Figures 2 and 3 are explanatory diagrams,

Figure 4 shows an oscillator circuit in which a crystal determines the frequency of oscillation,

Figure 5 shows a temperature control circuit which is operative to stabilise the temperature of the crystal.

It is possible to produce crystals which oscillate at a precisely constant frequency, provided the crystal is maintained at a fixed temperature. The value of the frequency is usually somewhat dependent on temperature, and although the temperature dependence of the frequency can be made very low, it is still nevertheless excessive for frequency sources which are required to exhibit a very precise and predetermined constant frequency regardless of variations in the ambient temperature in which the frequency source is to

be operated. It is therefore often necessary to carefully monitor and control the frequency of the crystal.

Referring to Figure 1, the lower drawing shows an elevation view of a frequency source and the upper drawing shows a plan view. The frequency source contains a crystal which operates at a precisely determined temperature.

A typical variation of frequency against temperature for a crystal is shown in Figure 2, and by way of example it is assumed that an oscillator circuit provides an output frequency of exactly 10 MHz at a crystal temperature of 75°C. It will be seen that the temperature characteristics of the crystal have been chosen with this operating frequency and temperature in mind, since the curve has a very shallow gradient at the temperature of interest. Thus even if the temperature varies slightly from the nominal value of 75°C, the resulting variation in frequency is slight. Even so, the temperature variation must be minimised so far as possible if a very stable frequency source is required, since even small frequency variations are unacceptable for certain purposes which have stringent frequency specifications.

Referring again to Figure 1, an oscillator circuit is formed on a ceramic substrate 1 and is mounted in close proximity to a crystal 2. The crystal 2 is held at a predetermined temperature by surrounding it with a thin copper foil 3 which acts as a thermal radiator, and which also surrounds a power transistor 4 which acts as a heat source, and a thermistor 5 which acts as a temperature sensor. The copper foil 3 has an excellent thermal conductivity so that temperature gradients in it are negligible. The transistor 4 is mounted in close proximity to a portion 6 of the foil which is positioned directly between the crystal 2 and the transistor 4. This serves to minimise the effect of temperature variations occurring on the surface of the transistor 4 itself, and further ensures that the crystal 2 is almost completely surrounded by the foil at an even temperature. The transistor 4 is operative to generate heat when the temperature as sensed by the thermistor 5 drops below a required and precisely predetermined value. The transistor 4 and the thermistor 5 both form part of a temperature control circuit which, like the oscillator circuit, is formed on a ceramic substrate 7 and is mounted in close proximity to the copper foil 3.

The two substrates 1 and 7, together with the crystal 2, the foil 3, the transistor 4 and the thermistor 5 are mounted on a rigid base 8 to form a compact and rigid assembly 30. This assembly 30 can be physically very small and, in practice, the base 8 is likely to be a printed circuit board which provides the necessary electrical interconnections between the various components of the frequency source. The space within the foil 3 is filled with a settable thermally conductive material which therefore encapsulates the crystal 2, the transistor 4 and the thermistor 5.

The assembly 30 is mounted within a container 9 which is in effect a thin walled closed box. The walls and roof of the container 9 are formed of a good conductive material such as copper, and its base 20 is formed of a robust electrically insulating material which provides support for the assembly 30. The container 9 is stabilised at a required temperature by means of four further thermistors 10, 11, 12 and 13. These further thermistors have positive temperature co-efficients of resistance, and differ from the thermistor 5 which has a negative temperature co-efficient. The characteristic of the thermistors 10, 11, 12 and 13 is shown in Figure 3, and they are arranged to operate on the linear portion of the characteristic between the points 31 and 32. These thermistors are connected in parallel across a power supply and they automatically stabilise the temperature of the container 9 at a predetermined temperature, as, if their temperature drops, it will be seen that their resistance decreases, and conversely their resistance increases with rising temperature. Assuming that the thermistors have a reasonably constant voltage drop across them equal to V volts, then the power dissipated is given by V^2/R. Thus as resistance R decreases, the power dissipation increases and hence their temperature rises. In this way the thermistors automatically stabilise at a temperature which is dictated primarily by the voltage applied to them.

Material 15, having very good thermally insulating properties, is present within the container 9 so as to surround the inner assembly on the printed circuit board 8. This material 15 is an expanded polyurethane which has a closed cell structure and therefore exhibits very good thermal insulating properties which assist the thermal stability of the assembly 30. The material 15 is formed in two portions; a flat portion 151 positioned between the base plate 20 and the printed circuit board 8, and a cap shape portion 152 which has a hollow rectangular recess which closely surrounds the assembly 30.

Container 9 is stabilised by the action of the thermistor 10, 11, 12, 13 so as to be held typically at a wall temperature of 55°C. This provides a significant temperature different relative to the crystal 2, which is held at about 75°C, and enables a positive control to be exercised on the temperature of the crystal 2 by the transistor 4 relative to the container 9 under the influence of this temperature difference — the heating action of the transistor is counter balanced by heat flowing from the assembly 30. As it is desirable that the heat flow from the assembly to the container 9 shall be as constant as possible to minimise temperature variations, the container 9 is mounted in an outer enclosure 18 which may be of metal or it may be of a plastics material. This outer enclosure 18 adopts the ambient temperature of the surroundings in which the frequency source is located. Again, an expanded polyurethane insulating material 19 fills the space between the container 9 and the enclosure 18.

This expanded polyurethane is a rigid material

and is sufficiently robust to support the internal parts of the frequency source without the need to provide separate mounting brackets to secure the container 9. However, the printed board 8 may be secured to the base plate 20 of the container 9 by means of rigid mounts 21, which could take the form of, for example, extended pins that also provide electrical connections to the outside of the unit and pass through insulating spacers 24. The electrical connections which must be made to the assembly 30 and to the thermistors located on the walls of the container 9 are made by means of flexible wires 23 which are embedded in the insulating material and which pass to connections on the base board 20. Further components that are required to select the operating temperature of the crystal are located on base plate 20.

As previously mentioned, the oscillator circuit is formed on a ceramic substrate 1. This circuit together with the crystal 2 and its associated components are illustrated in Figure 4. Those parts of the circuit which are formed directly on the ceramic substrate are shown within the broken line 40. The oscillator itself consists of a transistor 41 and an associated feedback loop which includes capacitors 42 and 43. The crystal 2 is connected to the base of transistor 41 and also to an external circuit consisting of a fixed capacitor 44, an adjustable capacitor 45 and a varactor diode 46. The nature and properties of the crystal 2 primarily determine the frequency of oscillation, and a capacitor 44 which is consistent with the require frequency of oscillation is selected at the time the operating frequency is decided upon. It is unlikely that the oscillator will initially produce exactly the required frequency, and capacitor 45 is therefore adjusted until the correct frequency is achieved. Capacitor 45 is shown in Figure 1 and a passageway 25 is left in the insulating material so as to provide external access to enable the adjustment of capacitor 45 to be effected. Once the adjustment has been set, the passageway 25 is blocked with a plug of thermally insulating material. The varactor diode 46, which is essentially a variable capacitor whose capacitance can be varied by the application of a d.c potential, is present so that the frequency of oscillation can be subject to fine adjustment after the frequency source has been manufactured. This fine adjustment is applied by means of a variable voltage at terminal 48.

The output of transistor 41 is coupled via a small capacitor 49 to an amplifier 50 which provides an output signal which is compatible with TTL circuits at terminal 51 for utilisation as required. The remainder of the components shown in Figure 4 are merely conventional biassing and voltage stabilisation components which are usually associated with an oscillator.

The temperature control circuit is shown in Figure 5 and those portions which are mounted on the substrate 7 are contained within the broken line 55. A resistor 56 is chosen in dependence on the operating temperature required, and it serves as a source of reference potential which is compared with the voltage drop across the thermistor 5. The thermistor 5 and the resistor 56 form part of a balanced bridge network which when unbalanced produces a difference signal which is amplified at a differential amplifier 57. The output of the amplifier 57 controls directly the current flowing through the power transistor 4 and hence the amount of heat which is applied to the radiating foil 3. A resistor 58, which is connected in series with the resistor 4, enables the current flowing through it to be monitored, so that current overload protection is provided by the transistor 59, which is rendered conductive when the current flowing resistor 58 exceeds a safe value.

Once the temperature of the copper foil 3 has stabilised, the transistor 4 is unlikely to draw full power, but during the initial warm up period, the current overload protection transistor 59 is operative so as to prevent the transistor 4 drawing excessive current which might damage it or its associated circuitry. If it is desired to operate the crystal at a different temperature, it is merely necessary to replace the resistor 56 with one of a different value.

As both the oscillator circuit and the temperature control circuits are mounted on very stable ceramic substrates 1 and 7 which are held at the temperature of the copper foil 3, the whole assembly operates in an extremely stable manner and its temperature is not significantly affected by variations in the external ambient temperature in which the outer enclosure 18 is situated. The transistor 4 serves to raise the temperature of the crystal 2 when its temperature drops below a required value, and the temperature gradient between the crystal 2 and the container 9 ensures that the heat loss from the crystal does not fluctuate unduly.

CLAIMS

1. A frequency source including a crystal controlled oscillator circuit; a common heat source operative to heat both the crystal and the oscillator circuit, which determines the frequency of the frequency source, to a required temperature; a temperature sensor operative to detect deviations from the required temperature and to control the heat source to compensate for the deviations; and a radiator of heat arranged to be heated by the heat source and which closely surrounds the crystal and the temperature sensor and which is in close proximity to said oscillator circuit.

2. A frequency source as claimed in claim 1 and wherein the radiator is arranged to also surround the heat source.

3. A frequency source as claimed in claim 1 or 2 and wherein the radiator is formed of a thin walled material which is a good conductor of heat.

4. A frequency source as claimed in claim 3 and wherein the radiator is a copper foil.

5. A frequency source as claimed in any of the preceding claims and wherein the heat source and the crystal are located immediately adjacent to each other with a portion of the radiation being

positioned between them.

6. A frequency source as claimed in any of the preceding claims and wherein, the oscillator circuit itself is positioned very closely adjacent to, but is not surrounded by, said radiator so as to be maintained substantially at the same temperature as the crystal.

7. A frequency source as claimed in any of the preceding claims and wherein a temperature control circuit is mounted very closely adjacent to said radiator so as to be maintained substantially at the temperature of the crystal.

8. A frequency source as claimed in claim 6 and wherein the major portion of the oscillator circuit is formed on a ceramic substrate.

9. A frequency source as claimed in claim 7 and wherein the major portion of the temperature control circuit is formed on a ceramic substrate.

10. A frequency source as claimed in claim 1 and wherein the crystal, the temperature sensor, the radiator, an oscillator circuit of which the crystal forms a part, and a temperature control circuit of which the temperature sensor forms a part, are all mounted together to form a rigid assembly and wherein the assembly is mounted within a closed container with thermal insulating material being present between the assembly and the inner surface of the container.

11. A frequency source as claimed in claim 10 and wherein means are provided for maintaining the surfaces of the container at a predetermined temperature which is less than the temperature of the crystal.

12. A frequency source as claimed in claim 10 or 11 and wherein the thermally insulating material is one which has a closed cellular structure.

13. A frequency source as claimed in claim 11 or 12 and wherein a plurality of temperature sensitive devices are mounted at the surface of the container and are operative to minimise the occurrence of temperature gradients in the walls of the container.

14. A frequency source as claimed in claim 13 and wherein said container has thin walls which are formed of a material having a very good thermal conductivity.

15. A frequency source as claimed in any of claims 10 to 14 and wherein said container is mounted within a larger container with further insulating material positioned between the two containers.

16. A frequency source substantially as illustrated in and described with reference to Figure 1 of the accompanying drawings.

17. A frequency source substantially as illustrated in and described with reference to Figures 1, 4 and 5 of the accompanying drawings.

New claims or amendments to claims filed on 12 May 1982.
Superseded claims: None.
New or amended claims:—

18. A frequency source including a crystal controlled oscillator circuit; a common heat source operative to heat to a required temperature the crystal, the oscillator circuit, which determines the frequency of the frequency source, and a temperature control circuit, which controls the heater; the temperature control circuit including a temperature sensor operative to detect deviations from the required temperature and to control the heat source to compensate for the deviations; major portions of the oscillator circuit and the temperature control circuits being mounted on one or more ceramic substrates; and a radiator of heat arranged to be heated by the heat source and which closely surrounds the crystal and the temperature sensor, and which is in close proximity to said oscillator circuit and temperature control circuit so that both circuits are maintained substantially at the same temperature as the crystal.

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